PLANKTON INVESTIGATION IN INLET WATERS ALONG THE COAST OF JAPAN

X. THE PLANKTON OF KAMAISI BAY ON THE EASTERN COAST OF TÔHOKU DISTRICT[1)]

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With 16 Text-figures

In Kamaisi Bay on the eastern coast of the Tôhoku District, about 100 km north of Onagawa Bay, a planktological survey was made by the same method as already mentioned on September 30, 1952. In this survey, the writer owed to the

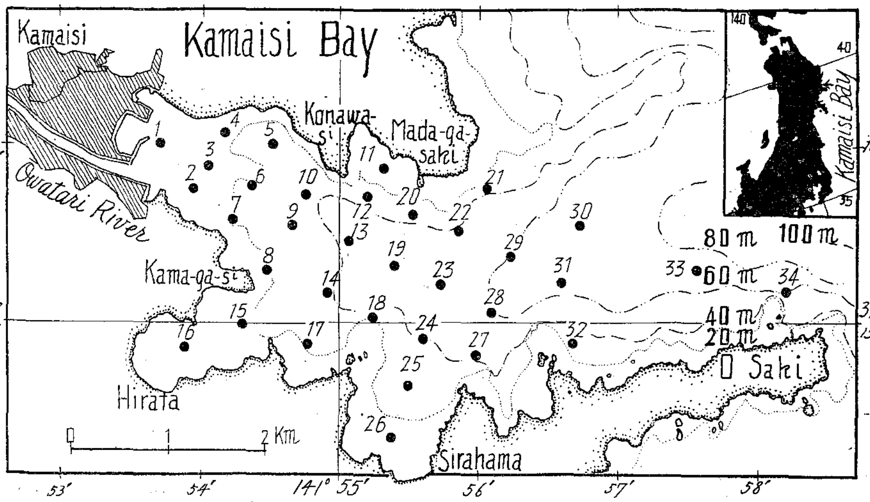

Fig. 1. Chart of Kamaisi Bay showing stations and bathymetric contours.

Iwate Prefectural Fisheries Experimental Station for permission to use the research boat. At this place the writer extends his sincere thanks particularly to Mr. K. GUNZI, Director of the station, and to Mr. T. HIROSE who participated in various ways of the investigation.

1) Contributions of the Seto Marine Biological Laboratory, No. 217.

Hydrological Conditions

Kamaisi Bay, lying on the north of Onagawa Bay, faces the Pacific Ocean with a rather wide mouth, about 2.5 km across. The interior of the bay is formed of three small inlets, named Kamaisi, Hirata and Sirahama respectively. The basin is relatively deeper than that of Onagawa Bay, the greatest depth near the mouth is about 60–80 meters, and 40 m isobath line enters into about the middle of the bay (Fig. 1). A small river Owatari-gawa passing through the Kamaisi city pours into the innermost region

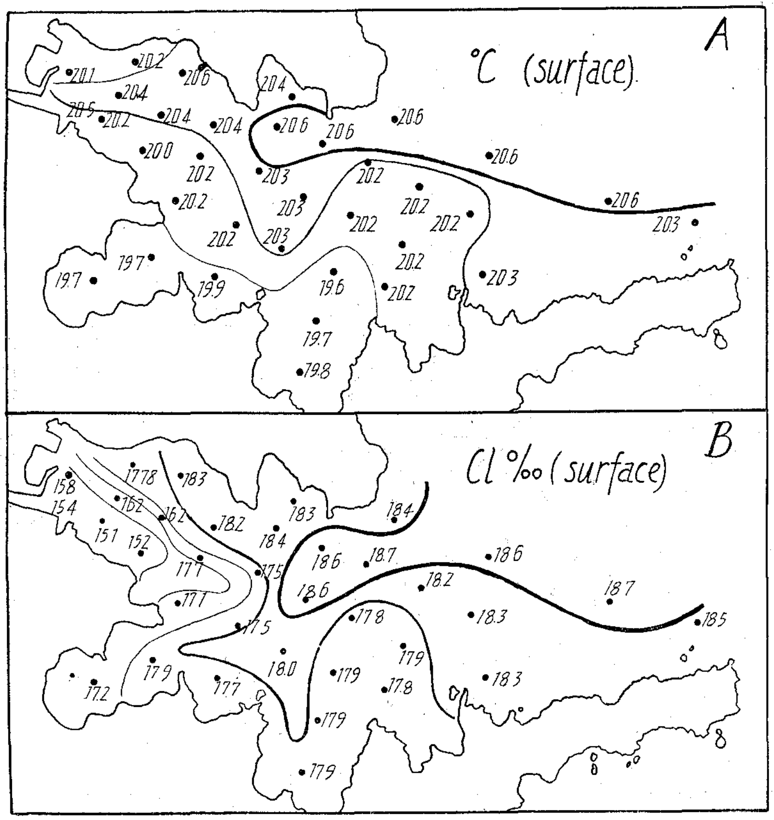

Fig. 2. Hydrological conditions during the survey. (September 30, 1952)
A. Distribution of surface temperature in °C.
B. Distribution of chlorinity in ‰ of the surface layer.

of Kamaisi inlet, and near the mouth many factories of the Kamaisi iron works are situated. Its river water and a large amount of waste discharged from these works influence on the southern area of the bay even towards the cape O-saki out of the bay.

Water temperature (Fig. 2, A) ; Surface water temperature was relatively uniform as a whole, ranging from 19.6°C to 20.6°C. It was lower in the southern area than in

the northern area and the open sea.

Chlorinity (Fig. 2, B) : The lowest chlorinity at the surface was found on the southern half of Kamaisi inlet (15–17 Cl ‰), where the river water pours into the bay. The highest chlorinities were found in the area from the mouth to the middle of the northern area (18.5–18.7 Cl‰), by the inflow of open sea water. In the southern area the chlorinity probably does not differ much from that in the northern area.

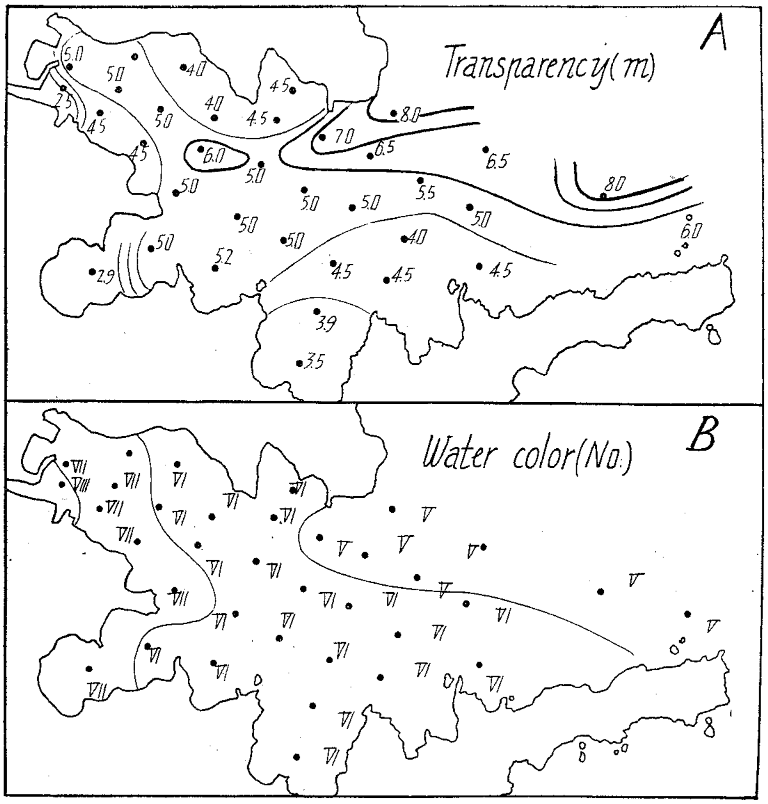

Fig. 3. Hydrological conditions during the survey.
A. Distribution of transparency in m.
B. Distribution of water color in no. of FOREL's scale.

Transparency and water color (Fig. 3, A and B) : The transparency of water was 3–5 m in the south and 5–8 m in the northern half of the bay. The water is much discolored near the estuaries of Owatari-gawa, being only 2.5 m in transparency and no. 8 in water colour. The water was clearer along the northern coast and the mouth (no. 5–6 FOREL's scale) than elsewhere.

Plankton

A. Quantitative Analysis of Plankton

The plankton samples were hauled at 34 stations (Fig. 1). The volume and total number of plankton are shown in Fig. 4, which gives respectively the value for one m haul. Both volume and number were very poor throughout all stations, and these were much smaller than in Onagawa Bay. The value was measured, ranging from a maximum of 0.03 cc to a minimum of 0.002 cc in the case of the volume and from

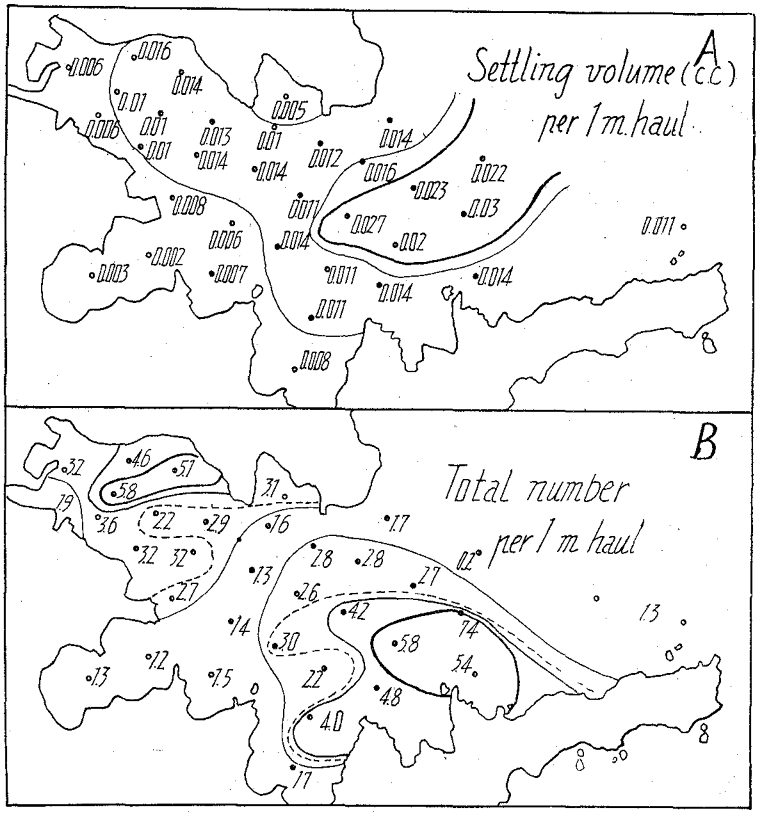

Fig. 4. Distribution of plankton in Kamaisi Bay (September 30, 1952).
A. Distribution of settling volume (cc) per one m haul from 15 m depth to the surface.
B. Distribution of total number of plankton per one m haul (unit of number is thousand).

5.8 thousands to 1.3 thousands of individuals, cells or colonies for total number of plankton per one m haul. The settling volume was the greatest in the central part of the mouth, and smallest in the Hirata inlet. The total number of individuals, cells or colonies was

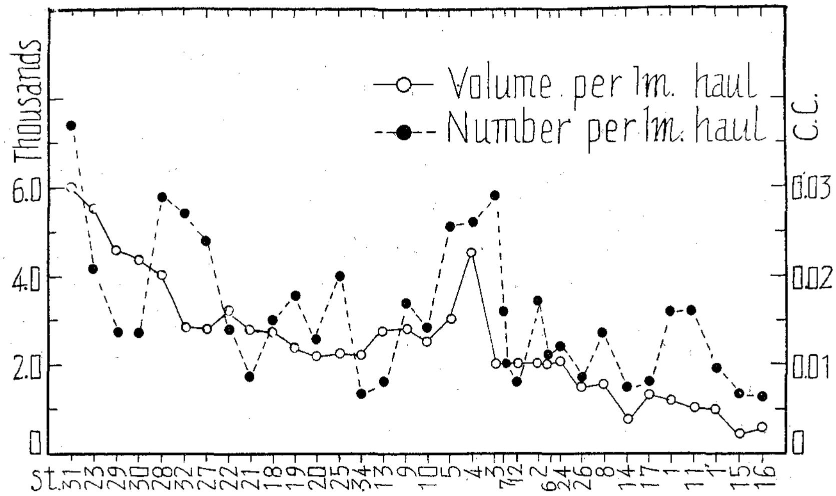

Fig. 5. Correlation between settling volume and total number of individuals, cells or colonies per one m haul.

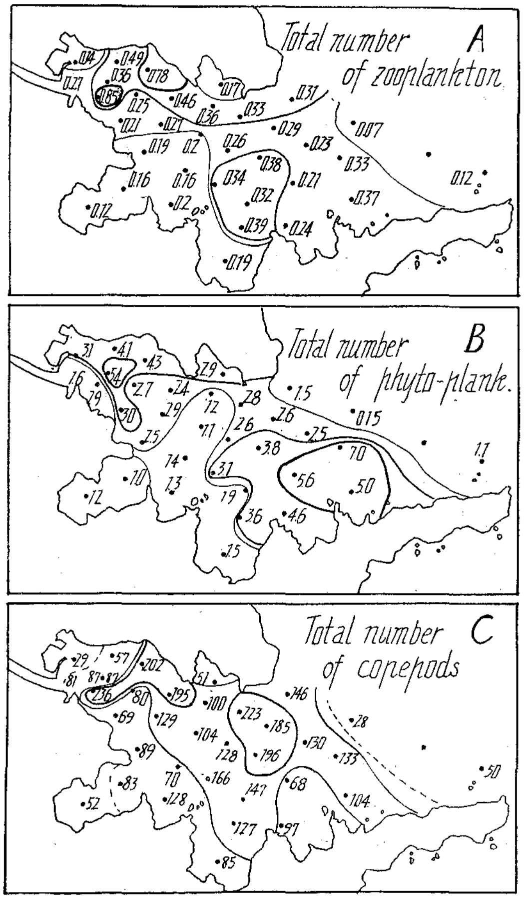

Fig. 6. Distribution of plankton in Kamaisi Bay.

A. Total number of zooplankton at each station (unit of number is thousand).

B. Total number of phytoplankton at each station (unit of number is thousand).

C. Total number of copepods (unit of number is individual).

the largest in the south-eastern part of the mouth and smallest in the central area across the bay from the Hirata inlet to the cape Mada-ga-saki of the mouth.

The relation between the settling volume and total number of plankton is generally parallel except for the outermost part of the bay, where the number was very small, but the volume was relatively large because of the large size of plankton (Sts. 29, 30, 21, 23, 13 and 34)(Fig. 4 and 5). From the inner part to the southern coast of the bay the number increases greatly. It is clear that this is due to the increase in number of diatoms. In most parts of the Kamaisi and Hirata inlets, both volume and number are very small.

The population of zooplankton was poor throughout all stations as in the case of Onagawa Bay (Fig. 6, A). It was, however, largest in the middle area of the Kamaisi inlet, and smallest in the mouth and southern two inlets. The numerical percentage

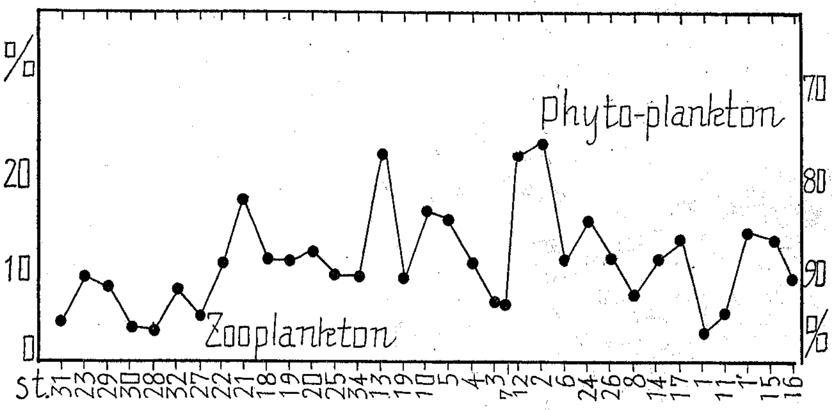

Fig. 7. Percentage composition between zoo- and phytoplankton per one m haul.

of zooplankton in the total plankton (Fig. 7) was also large as in the case of Onagawa Bay. The values generally increased towards the inner part of the bay. The population of phytoplankton was also poor (Fig. 6, B); it was, however, found denser in the southern area of the mouth (about 5–7 thousand cells or colonies and 93–97% of total plankton) and northern part of the Kamaisi inlet (about 3–5 thousands and 85–94%) than in the northern (about 2–3 thousands), mouth region (about 0.2–1.5 thousands and 90–96%) and southern area including two inlets, Hirata and Sirahama (about 1–1.5 thousands and 86–91%)(see Fig. 7).

B. Qualitative Analysis of Plankton

Zooplankton

As shown in Fig. 8, the important components of zooplankton were copepods (20–65%), protozoans (10–65%), the other various animals (1–10%) and larvae of animals (10–65%). Of these animal plankters, the copepod was the most important

in numerical abundance and frequency of occurrence. Fig. 8 shows the variety of number and percentage composition at each station. The total number of copepods (Fig. 6, C) was greatest in the Kamaisi inlet, while towards the estuary of Owatari-

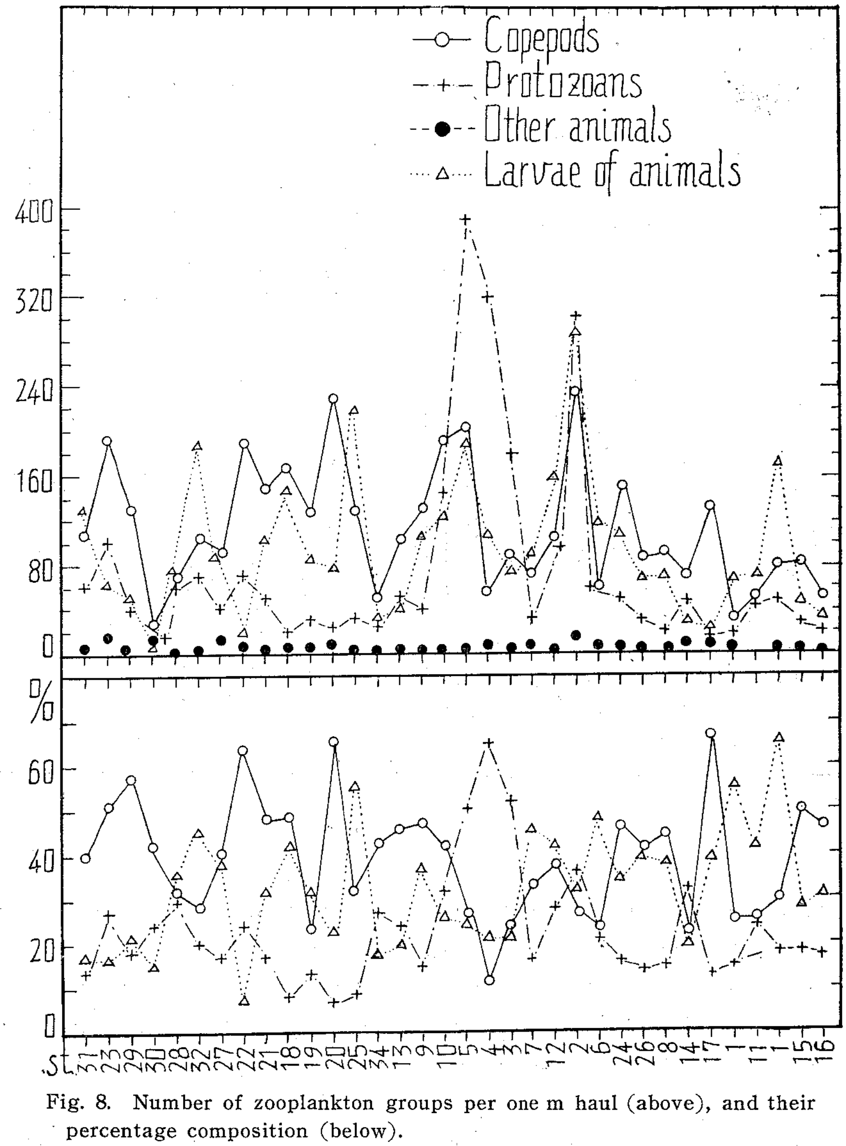

Fig. 8. Number of zooplankton groups per one m haul (above), and their percentage composition (below).

gawa and towards the southern outermost part of the bay it suddenly decreased. And also it decreased outwards the bay from the center of the bay.

Among the copepods the following 28 species were remarkable (unit of number is individual per one m haul)......See Table on p. 198.

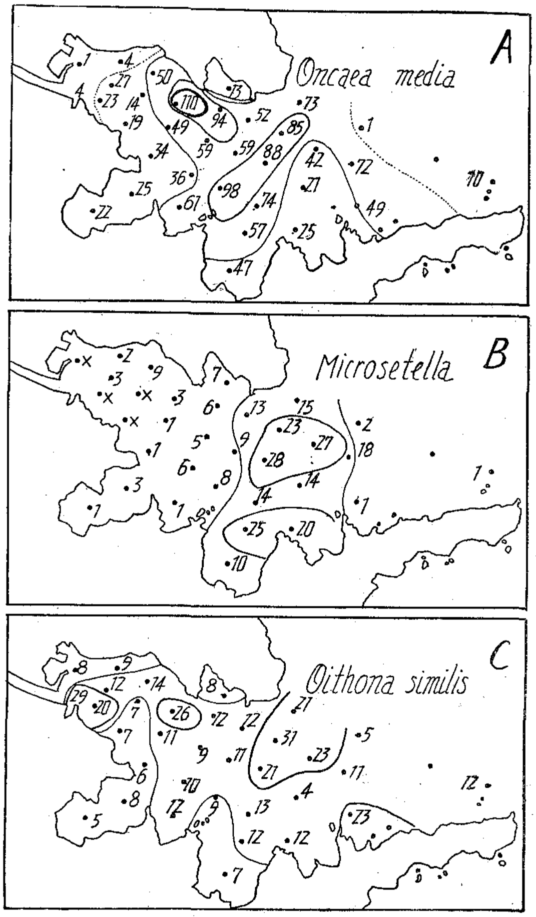

Fig. 9. Distribution of important copepods per one m haul.

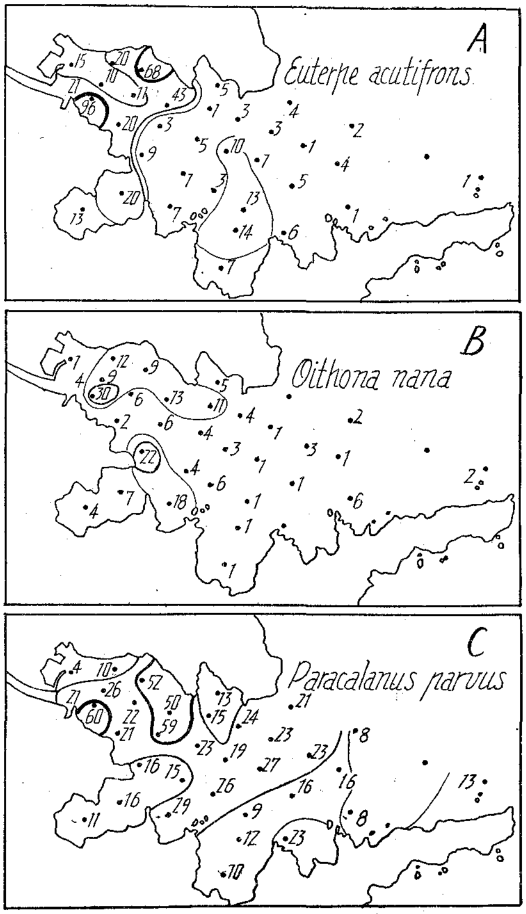

Fig. 10. Distribution of important copepods per one m haul.

Among them the offshore and neritic species were widely distributed throughout all stations except the innermost part of Kamaisi and Hirata inlets.

Oncaea media (Fig. 9, A and Fig. 11) was predominant among copepods, and occurred mainly in the central region of the bay, where it reached about 50–110 individuals and 30–65% of the total copepods per one m haul. It was, however, comparatively sparse in the mouth and innermost part of the Kamaisi inlet. *Paracalanus parvus* (Fig. 10, C) was abundant in the northern half of the bay and decreased towards the southern half and the mouth (about 10–60 individuals and 7–40% of the composition. *Euterpe acutifrons* (Fig. 10, A) was rather restricted to the Kamaisi inlet (about 20–100 and 10–52%), being only sparsely found elsewhere (about 1–20 individuals and 1–20%).

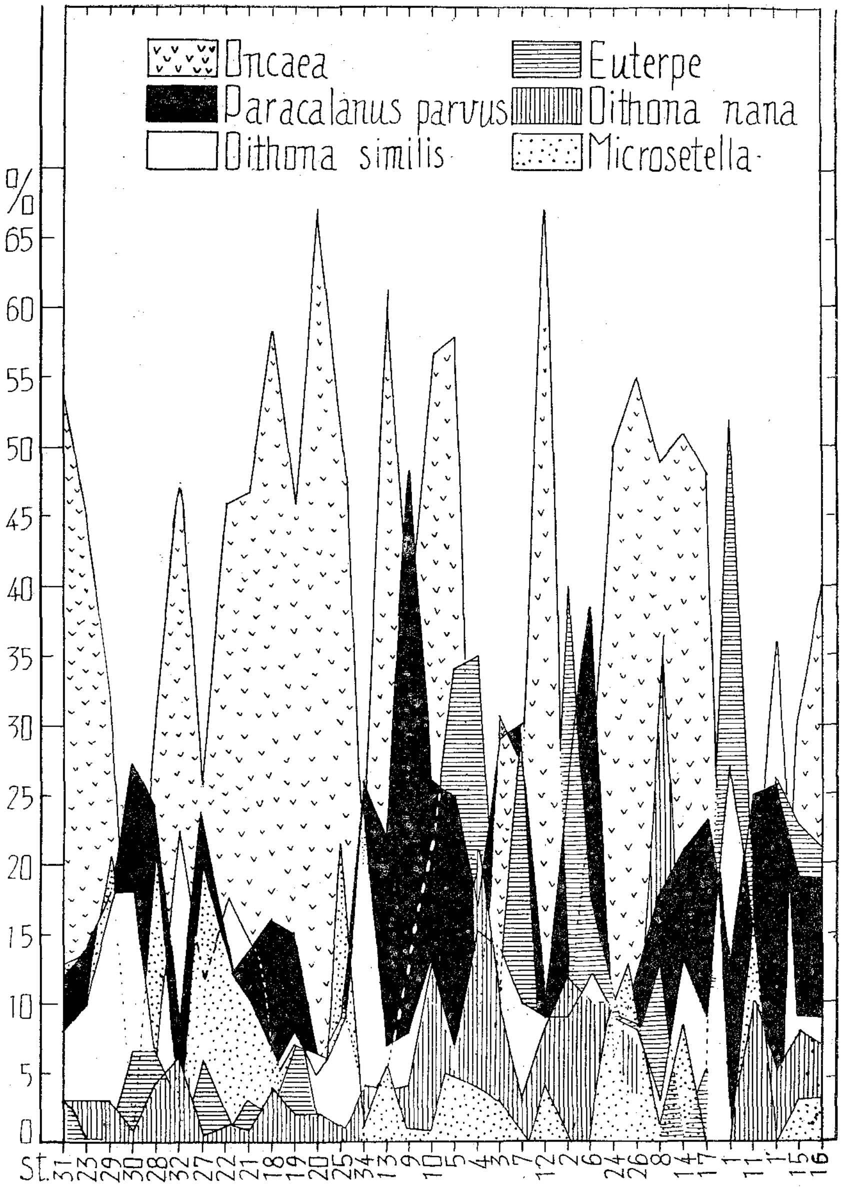

Fig. 11. Percentage composition of important copepods per one m haul at each station.

Species \ Number of individual	Kamaisi inlet	Hirata inlet	Sirahama inlet	Southern area of the bay	Northern area of the bay	Mouth of the bay
Oncaea media	3–58	30–39	45–55	30–58	35–67	20–54
Paracalanus parvus	13–46	19–20	9–12	20–30	12–26	12–27
Euterpe acutifrons	2–52	22–23	8–11	1–23	1–10	2– 3
Oithona similis	3–36	9–10	8– 9	5–13	5–17	8–24
Oithona nana	0–32	7–14	1– 2	1–14	2–12	0– 6
Microsetella norvegica	0– 5	2– 3	12–20	2–20	1–14	1–13
Coricaeus crassiusculus	0– 3	+	+	+	+	0– 3
Oithona rigida	+	+	+	1– 3	1– 3	1– 4
Acartia clausi	0– 3	2	0– 1	0– 2	+	–
Acartia negligens	–	–	–	–	+	+
Centropages bradyi	+	–	–	+	+	2– 7
Clitemnestra rostrata	–	–	–	–	+	–
Oithona plumifera	–	+	+	+	0–4	1– 7
Copilia longistylis	–	–	+	+	+	+– 1
Oncaea venusta	–	–	+	+	+	1– 3
Candacia sp.	–	–	–	+	+	+
Temora discaudata	–	–	–	+	+	+
Temora stylifera	–	–	+	+	+	–
Calanus helgolandicus	–	–	–	+	+	+
Calanus tenuicornis	–	–	+	+	+	+
Calanus minor	+	–	+	+	+	+
Calanus darwinii	–	–	+	+	+	+
Eucalanus crassus	–	–	–	–	+	–
Eucal. attenuatus	–	–	–	+	+	+– 2
Calocalanus pavo	+	–	–	–	+	–
Paracalanus aculeatus	–	–	–	+	+	+
Clausocalanus furcatus	–	–	+	+	+	+
Holoptilus longicornis	–	–	+	+	–	–

Oithona nana (Fig. 10, B) which is a true inlet species showed a similar distribution, although it was markedly smaller in number and percentage composition (about 10–30 individuals and 2–30% from the Kamaisi inlet to the mouth of Hirata inlet, and 1–10 individuals and 1–10% in the other stations) than in the various bays and inlets already surveyed. *Oithona similis* (Fig. 9, C) was of approximately the same number almost everywhere, although more abundant northwards than southwards. *Microsetella norvegica* and *M. rosea* Fig. 9, B) were found chiefly in the central area of the mouth, showing 10–20% and 10–30 individuals, while very scarce elsewhere. *Acartia clausi*, which was the most important component in the inner part of Onagawa Bay, was very sparsely found in the inner part and not found in other outer areas. From the distribution of these neritic forms and their comparative abundance, it seems probable

that the inner area of the bay is affected strongly by the land water. But, at the stations of the central and outer part of the bay were found many oceanic copepods such as *Calanus, Eucalanus, Acrocalanus, Clausocalanus, Copilia, Candacia, Oncaea, Coricaeus,* etc., and they have little intruded into the innermost part of the bay and inlets, as indicated in the appended table (see left).

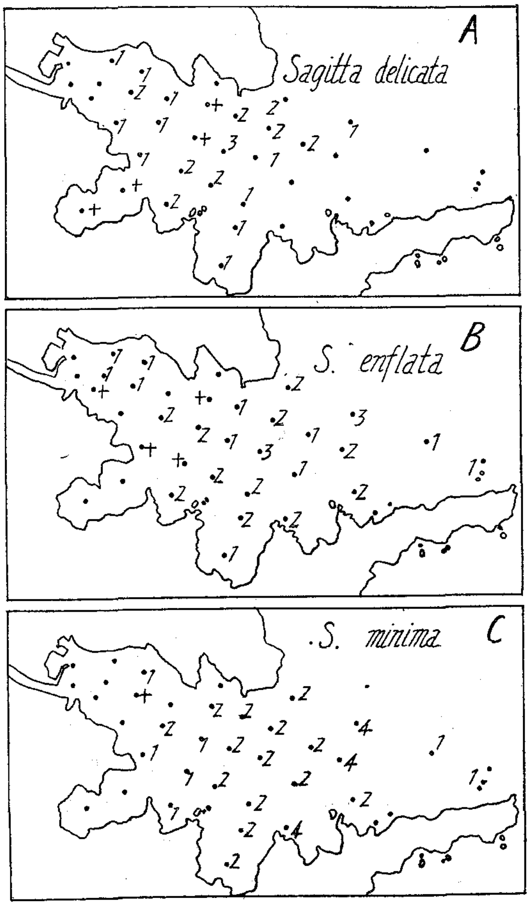

Fig. 12. Distribution of chaetognaths per one m haul at each station.

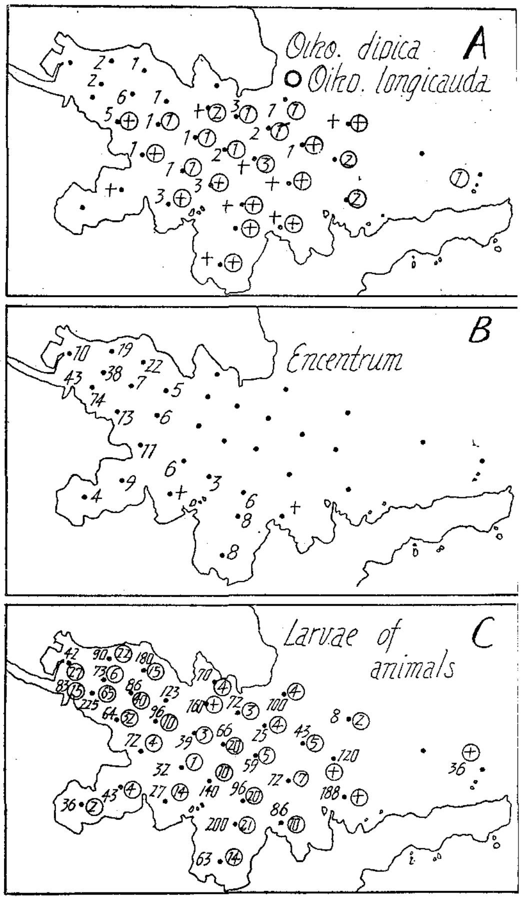

Fig. 13. Distribution of zooplankton. A, The number in the circle shows the individual number of *Oik. longicauda.* C, the number in the circle shows the total number of animal groups except copepod nauplii. The number not encircled shows the copepod nauplii.

The cladocerans such as *Penilia schmackeri, Evadne tergestina* and *Podon* sp. were widely distributed, but they were very scarce. *Sagitta enflata* and *S. minima* both of

which are the oceanic warm water species occurred at almost all stations except for the innermost two inlets, but at each station were found only a few individuals per one m haul (Fig. 12, B and C). *Sagitta delicata* was also widely distributed, but it was very poor (Fig. 12, A). Many small individuals of *Sagitta* were caught at all stations. Among copelates *Oikopleura dioica* and *Oikopleura longicauda* occurred widely in small number (Fig. 13, A). A few individuals of *Fritillaria haplostoma* and *Frit. pellucida* were found in the outer region of the bay. *Doliolum nationalis* was very scarce. A littoral rotifer *Encentrum* sp. (cf. *E. marinum*) was found frequently in the Kamaisi inlet and southern coast area of the bay (Fig. 13, B), while absent in the outer part of the bay. Hydromedusae were found singly in all parts of the bay but could not be determined.

Among protozoans, *Stycholonche zanclaea* was widely distributed at all stations at the frequency of 5–60%, although it was the most abundant in the Kamaisi inlet (about 50–300 individuals and 10–60% of total number of plankton) and decreased gradually outwards. *Favella campanula* was also numerous in the Kamaisi inlet and decreased towards the southern parts of the bay. Of other tintinnoids, *Tintinnopsis beroidea, Tin. cylindrica, Tin. nordquisti, Tin. mortensenii, Coxiella* sp., *Favella ehrenbergi, Rhabdonella longa, Tintinnus lusus-undae, Tin. lectus, Tin. turris, Tin. acuminatus,* and *Rhabdonella* sp. were frequent.

The main components of larval forms were copepod nauplii, larvae of polychaetes and small number of pelecypod and gastropod veligers. Copepod nauplii were numerous all over the bay, and increased towards the inner part of the Kamaisi inlet (Fig. 13, C). The larvae of polychaetes were also distributed widely at all parts, but they were restricted to the inner part of the bay.

PHYTOPLANKTON

The most distinguished features of the composition and population of the phytoplankton were: (1) the poorness in total number; (2) the invasion of many species of oceanic forms into the greater part of the bay; (3) the fairly rich diatoms along the southern coast; (4) the relatively rich dinoflagellates in quantity and quality. The total number of phytoplankton at these stations only amounts to 7 thousands of cells or colonies per one m haul at the richest stations (Fig. 6, B, Fig. 14, A–C and Fig. 15, A–C). The population was composed of diatoms, *Thalassiothrix Frauenfeldii, Chaetoceros didymus, Ch. laciniosus, Ch. curvisetus,* etc., and they occurred considerably in abundance in the northern part of the Kamaisi inlet and along the southern half of the mouth of the bay. The other northern and mouth parts of the bay were also occupied by the same species, associated with the oceanic species which seem to have been directly carried in with the inflowing open sea water.

Many offshore and neritic dinoflagellates were found more abundantly in the outer part than in the inner part, that is, *Ceratium trichoceros, Cer. deflexum* (Fig. 15, C),

Cer. tripos, *Cer. candelabrum* (Fig. 15, B) and small number of *Cer. masciliense*, *Cer. macroceros*, *Cer. intermedium*, *Cer. molle*, *Cer. smatoranum*, *Cer. extensum*, *Cer. fusus*, *Cer. furca*, *Cer. lineatus*, *Cer. gibberum*, *Cer. berone*, *Peridinium grande*, *Per*, *pellucidum*, *Per. oceanicum* var. *oblongum*, *Per. conicum*, *Per. depressum*, *Pyrocystis noctiluca*, *Pyr. fusiformis*, *Pyr. lunula*, *Pyrophax horologicum*, *Ceratocorys horrida*, *Dinophysis candata*, and *Din. homunculus*, etc. Besides, still more population with *Chaetoceros coarctatus*,

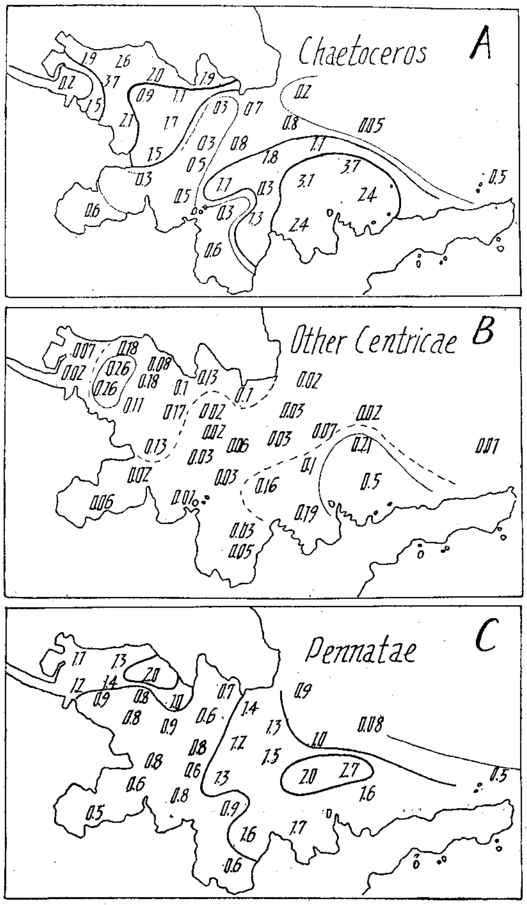

Fig. 14. Distribution of important groups of diatom.

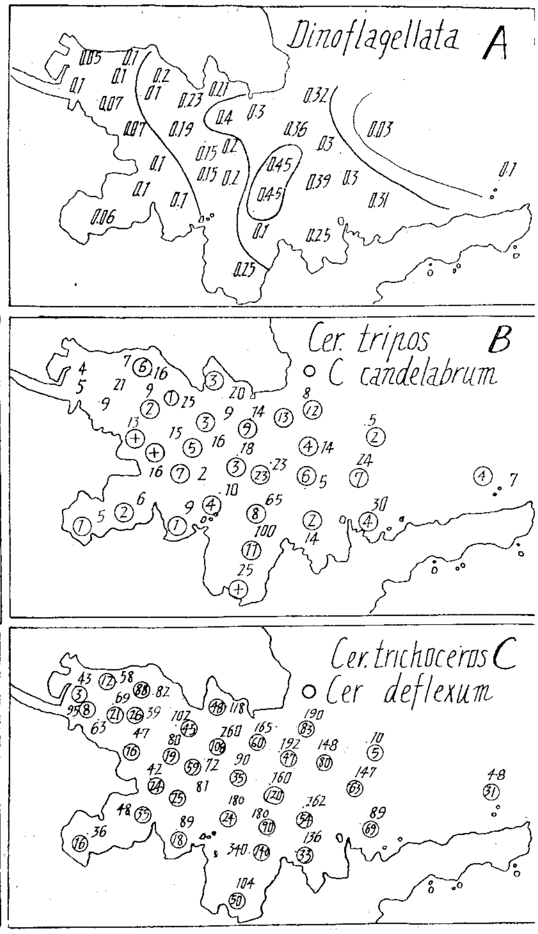

Fig. 15. Distribution of important dinoflagellates.

A. Total number of dinoflagellates (unit of number is thousand).

B. Distribution of *Cer. tripos* and *Cer. candelabrum* (encircled).

C. *Cer. deflexum* (encircled) and *Cer. trichoceros*.

Ch. peruvianus, Ch. tetrastichon, Hemidiscus Hardmanium, Rh. calcar-avis, Rh. alata forma *gracillima* and *Rh. hebetata*, etc. These oceanic diatoms were rather small in number and mingled with many neritic forms. Among the other Centricae, *Ch. atlanticus* var. *neapolitana, Ch. densus, Ch. constrictus, Ch. decipiens, Ch. Lorenzianus, Ch. affinis, Ch. brevis, Ch. costatus, Ch. paradoxum, Rh. setigera, Rh. imbricata, Skeletonema costatum, Coscinodiscus excentricus, Cos.* spp., *Corethron hystrix, Bacteriastrum hyalinum, Dactyliosolen mediterraneus, Leptocylindrus danicus, Climacodium biconcavum, Biddulphia sinensis, Bidd. mobiliensis* and *Hemiaulus Hauckii* were remarkable (Fig. 14, B). The Pennatae, such as *Thalassiothrix longissima, Thalassionema nitzschioides, Asterionella japonica, Pleurosigma* sp., *Nitzschia seriata* and *Navicula* sp. also showed almost the same distribution (Fig. 14, C).

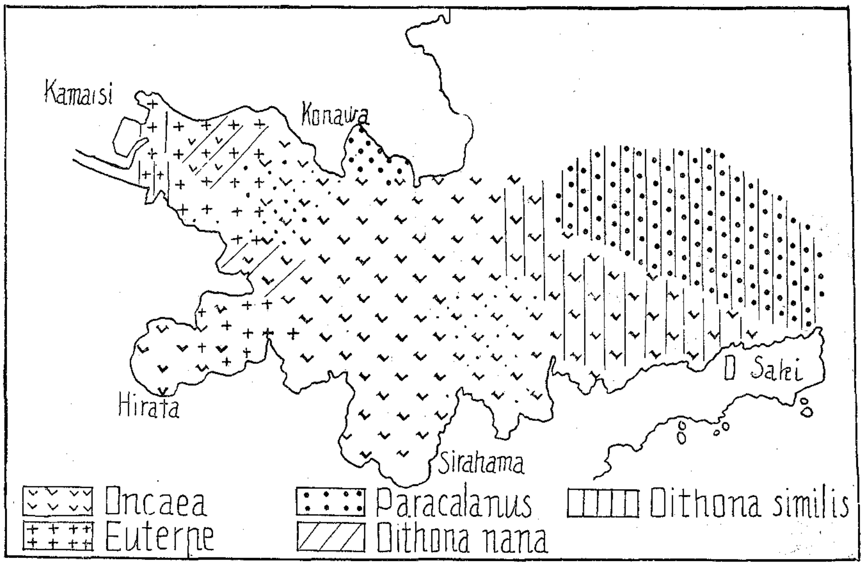

Fig. 16. Distribution of dominant copepods in Kamaisi Bay. (September 30, 1952)

General Consideration on Regional Distribution

The most remarkable feature in this bay is the relatively great abundance of oceanic forms which indicates clearly a strong inflow of Pacific open sea water more than in Onagawa Bay. For example, many of the oceanic forms involving dinoflagellates, diatoms, copepods, chaetognaths and tunicates are evenly distributed in almost all parts of the bay except only the innermost part of the inlet areas.

On the bases of the distribution of the dominant copepods and their relative abundance in this bay, the following three main communities may be recognized as shown in Fig. 16.

1. *Euterpe* community.

Euterpe acutifrons concentrated in the Kamaisi inlet and was predominant among all plankters in the Hirata inlet. It was associated with *Oithona similis, Paracalanus parvus, Oncaea media* and small number of *Oithona nana*. As other associates a rotifer *Encentrum* and a copelate *Oikopleura dioica* were remarkable. Abundant neritic diatoms and small number of oceanic diatoms and dinoflagellates occurred also there. The population of both zoo- and phytoplankton was relatively large in this bay. At the innermost stations of the Kamaisi inlet the productivity was very poor; there were found almost all the species occurring in the bay, but in much smaller numbers. The water is less saline and much stagnated and polluted by industrial sewage.

2. *Oncaea* community

At almost all the stations, except for the innermost of the inlet and the mouth, *Oncaea media* is predominant. The whole area occupied mostly by this species was associated with *Paracalanus parvus, Oithona similis* and many other oceanic copepods and diatoms. In this area the same local patches of population are found. The productivity is relatively small, although it varied according to stations. The distribution of both zoo- and phytoplankton in this area was somewhat complicated, partly because of the different hydrological conditions favourable to various forms. In the central part of the bay, where the population is much poor, the oceanic inflow is very plentiful and the water turbulence is strong. In the southern area near the coast the productivity is large, occupied by abundant neritic diatoms. Thus it may be supposed that the water in the area is furnished with nutrient salts discharged from the river at the head of Kamaisi inlet, flowing along the southern coast into the bay, even if the surface water is contaminated.

3. *Paracalanus parvus—Oithona similis* community.

The mouth part of the bay was represented mainly by *Paracalanus parvus* and *Oithona similis* in the percentage composition, and associated with *Oncaea, Microsetella,* large number of oceanic copepods, tunicates, chaetognaths, protozoans, diatoms and dinoflagellates. The productivity is very small. The water is relatively violent and shows higher transparency and salinity, and lower water color than in the preceding areas occupied by the *Oncaea* community.

Generally speaking, Kamaisi and Onagawa bays, which are formed of short embayments with a wide mouth and deep basin, are much more directly influenced by the open sea water and ocean current than the bays or inlets with the narrow mouth and shallow basin. The water is highly saline even towards the head. The productivity in both bays, which are not far apart from each other, is similarly poor, as compared with that in shallower bays such as Nagasaki, Akkesi and Ago Bay. The

composition and the manner of distribution of plankton, especially of zooplankton of Kamaisi Bay were very different. Although such differences may be partly referred to the seasonal succession, it seems probable that the effect of the topographical and hydrological features characterizing the rias coast is not negligible. From a comparison between the plankton communities of the Kamaisi Bay and Onagawa Bay, it becomes clear that, (1) in Kamaisi Bay there were more numerous oceanic species than in Onagawa Bay in respect to diatoms, dinoflagellates, copepods, tunicates and chaetognaths. (2) The number of species was more numerous in Kamaisi Bay. (3) The innermost area of the inlets in Kamaisi Bay is represented by the communities of *Euterpe acutifrons*, *Oithona similis* and *Paracalanus parvus*, instead of the *Acartia clausi*—*Oithona nana* community which is usually found in most of the bays.